PRELIMINARY NOTES ON SOME IGNEOUS ROCKS OF JAPAN. IV[1]

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IV. ON LAVA AND ANORTHITE-CRYSTALS ERUPTED FROM THE TARUMAI VOLCANO IN 1909

Introduction.—The volcano Tarumai is located at a distance of about 42 kilometers south of Sapporo, the chief city of Hokkaido. Though the volcano has long been known as one of the active volcanoes in the district, it has become the object of special attention since the outpouring of lava, which took place in April, 1909, forming a dome of 134 meters in height as measured from the neighboring ground, and adding 40 meters to the pre-existing highest peak of the mountain, which is 1,015 meters above the sea-level, according to Ōinoue's report.

A revival of the exhausted volcanic energy, which had remained in the solfataric state since the comparatively great explosion of August 17, 1895, took place at the beginning of the year 1909. After that several outbursts and shocks were reported from the region. At last, in the course of about 24 hours, from the evening of the 17th to that of the 18th of April, lava of about 20,000,000 cubic meters in volume, measured by B. Koto, was poured out of the explosive crater, and a dome was formed which is shown in the accompanying photographs (Figs. 1 and 2).

Reports of the event, written in Japanese by D. Satō and Y. Ōinoue, have been published by the Imperial Geological Survey of Japan and the Earthquake Investigation Committee, respectively. The following brief petrographic description was made by the writer on the specimens collected by D. Satō.

Megascopical characters.—The specimens at hand have in general a glassy and ragged appearance. Those taken from the ejecta are

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of light-colored pumice. In their inner part the cellular structure appears well developed, while the outer thin crust is usually glassy and compact, strongly marked by cracks, which are char-

FIG. 1.—View of the new dome from the east, May 11, 1909 (by T. Kawasaki Imp. Geol. Surv. of Japan).

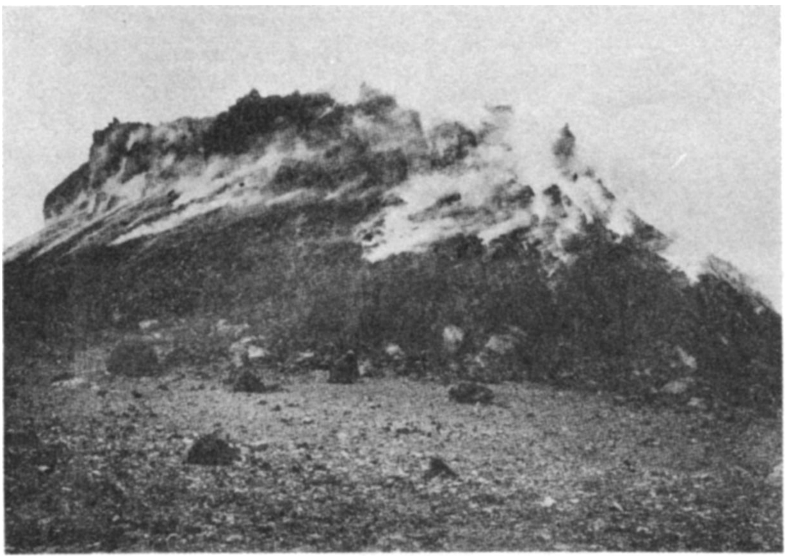

FIG. 2.—View of the new dome from the southwest, May 11, 1909 (by T. Kawasaki).

acteristic of the so-called bread-crust bombs. This variety contains well-formed anorthite crystals of considerable size, with an average length of 13 mm. Beside these, there are not a few small

megascopic phenocrysts of feldspar and pyroxene, their sizes varying from 1 mm. to 2 mm. The other specimens taken from the new dome are dark gray, or reddish dark gray, in color and spongy or ragged in appearance. Generally, they are characterized by heterogeneity in texture due to their variable crystallinity, and by flow-structure, which is visible in the lava-mass, as shown in Fig. 3.

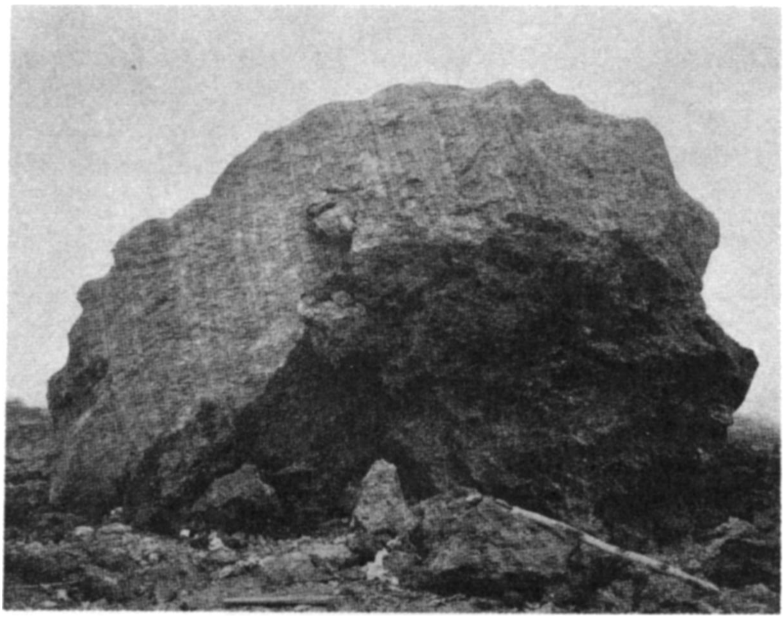

FIG. 3.—Lava-block, showing the marked flow-structure

Sometimes dark-gray to light-gray cryptocrystalline masses are imbedded along the planes of flow in the rock-mass, their shapes being mostly lenticular.

Microscopical characters.—The rock is made up of plagioclase, hypersthene, augite, olivine, magnetite, apatite, and microliths, scattered in the abundant glassy groundmass. The prevailing phenocrysts are of anorthite. Hypersthene comes next, and is nearly equal to, or is more than, the augite. Subhedral magnetite is not rare as phenocrysts. Though olivine appears abundantly associated with the large crystals of anorthite, mostly as peripheral

inclusions, it is rarely met with in the general mass, and may be considered as an accessory constituent of the rock.

The matrix exhibits different textures, according to different conditions under which the lava consolidated. The crustal part of the ejecta is hypohyaline, while its inner part usually shows typical cellular structure, the glass base being colorless. The specimens taken from the dome are more crystalline than those just described, but there is still abundant residual glass. It is moderately clouded with magnetite dust and pyroxene microliths. The megascopically cryptocrystalline part appears holocrystalline under the microscope and consists essentially of granular pyroxene and feldspar, scattered microporphyritically with skeletal crystals of hypersthene.

Feldspar.—The feldspar phenocrysts are of two kinds. One of them is well-formed anorthite of considerable size, 13 mm. in average length. Zonal structure is nearly wanting, or is indistinct. These occur in the ejecta and peripheral part of the lava, or even as isolated crystals, suggesting that their crystallization was prior to that of other minerals. The other variety is smaller in size, with an average length of 2 mm., and is commomly subhedral in shape, sometimes with a strongly curved outline invaded by the glassy groundmass. This variety differs from the first in possessing zonal structure due to variation in the chemical composition and to the arrangement of abundant inclusions. In average composition, the second variety is slightly more sodic than the first. The most abundant inclusions are light-brown or colorless glass with air bubbles in many instances. Apatite and magnetite are also present, commonly in small quantity. In some crystals pyroxene appears as inclusions, but more commonly the feldspar is abundantly inclosed in the hypersthene and augite phenocrysts and shows a distinct automorphic relation toward the pyroxene. The larger crystals will be more fully described in the second part of this article.

Pyroxene.—The hypersthene is easily distinguishable from the augite by marked pleochroism, low double refraction, parallel extinction, and crystal habit. It occurs in crystals of two periods of crystallization. The largest phenocrysts are 2.5 mm. in length

along the axis *c*. Pleochroism is distinct; α=reddish brown, β= greenish yellow, γ=yellowish green. It is optically negative, the optic plane being parallel to the orthopinacoid. There are abundant inclusions of plagioclase, magnetite, glass, and a few crystals of apatite; of these the plagioclase is large and conspicuous. The smaller hypersthene is rather euhedral in shape and is sometimes marked with transverse cracks perpendicular to the axis *c*.

Augite crystals are anhedral to subhedral, and also have abundant inclusions, just as the orthorhombic pyroxene. Parallel growth with the hypersthene is common, the hypersthene always being inclosed by augite. Twinning parallel to the orthopinacoidal face commonly occurs, and that parallel to (101) is rare.

Olivine crystals, as already stated, occur in association with the large crystals of anorthite and have well-defined form, elongated along the vertical axis with a length of about 2 mm. The predominating faces, easily identified by the naked eye, are *m*(110), *k*(021), and *b*(010). They are usually coated by a dark-reddish colored, thin crust. They frequently occur in groups of several individuals associated with a smaller quantity of magnetite grains. Notwithstanding the noticeable fact that olivine is nearly absent, or very scarce, in the general mass of the rock, it appears abundantly as peripheral inclusions of the large anorthite.

Magnetite occurs frequently as phenocrysts in association with those of pyroxene, and varies in size from 0.1 mm. to 0.3 mm., in striking contrast with the same mineral in the groundmass, which appears as dusty grains.

Apatite usually occurs as needle-shaped inclusions, but in a few instances larger crystals with a violet color, finely striated parallel to the vertical axis, appear in the groundmass.

Chemical characters.—The analysis of the rock made by N. Yoshioka in the chemical laboratory of the Imperial Geological Survey of Japan is as follows:

SiO_2	60.93
Al_2O_3	16.46
Fe_2O_3	3.35
FeO	5.94
MgO	2.88

CaO	7.84
Na_2O	1.44
K_2O	0.79
H_2O	n.d.
TiO_2	0.42
P_2O_5	0.13
MnO	0.55
	100.78

The norm, calculated from the above figures, is given below:

Quartz	25.1
Orthoclase	5.0
Albite	12.1
Anorthite	36.1
Diopside	2.1
Hypersthene	13.6
Magnetite	4.9
Ilmenite	0.8
	99.7

The ratios are:

$$\frac{\text{Sal}}{\text{Fem}} \dots\dots 3.66$$

$$\frac{Q}{F} \dots\dots 0.47$$

$$\frac{K_2O' + Na_2O'}{CaO'} \dots\dots 0.25$$

$$\frac{K_2O'}{Na_2O'} \dots\dots 0.39$$

By the Quantitative System the rock would be classified under the name bandose.

In this classification, it may be noted that the rock is characterized by a high percentage of lime, which appears mostly as modal anorthite, and by the comparatively high silica content.

Generally speaking, the mineralogical and chemical characters of the latest lava of Tarumai volcano seem to be representative of

those of the modern pyroxene-andesites, which are widely spread over the Japanese Islands, judging from a cursory glance over the volcanic rocks of Japan. For this reason the name bandose appears to be particularly appropriate.

ANORTHITE-CRYSTALS IN THE LAVA OF 1909

The occurrence of the larger crystals of anorthite is noteworthy. The crystals form large phenocrysts in the lava, and have been

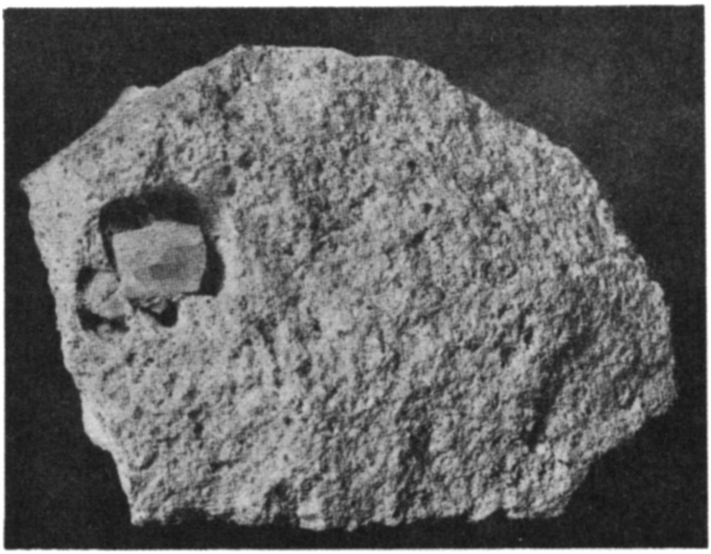

FIG. 4.—Cavity with anorthite crystal. Natural size

ejected separately also as the so-called "anorthite bombs," and are scattered abundantly around the crater; as is the case with the anorthite on Miyake-jima,[1] one of the Seven Izu Islands, Zao-san, a volcano in the province of Rikuzen, and Iwate-san, a volcano in the province of Rikuchu; the oligoclase-andesine[2] on Naka-iō-jima, one of the Sulphur Islands, may be cited as the parallel examples.

[1] Kikuchi, "On Anorthite from Miyake-jima," *Journal of the College of Science, Imp. Univ. Japan*, II, Part I, p. 31.

[2] Wakimizu, "The Ephemeral Volcanic Island in the Iōjima Group (Sulphur Islands)," *Publications of the Earthquake Investigation Committee*, 1908, No. 22 C, Tokyo.

A black, thin coating of lava, which crusts the Miyake-jima anorthite and the Naka-iō-jima oligoclase-andesine, is not seen on the mineral from Tarumai. The crystals, however, have attached to them a small quantity of light-colored pumice. It is evident that the matrix of brittle pumice separated easily from the crystals and that the semi-solidified lava was not so viscous as in the case of the lava of Miyake-jima and of Naka-iō-jima. Also, in some specimens the crystal is in a cavity having well-defined

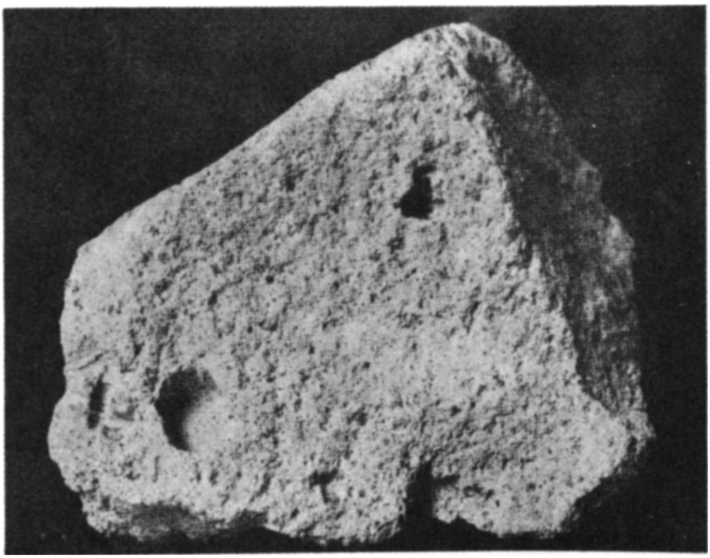

FIG. 5.—Well-defined cavity from which the anorthite crystal has been lost. Natural size.

walls corresponding to the faces of the crystal, with a space about 4 mm. in width between the crystal and the lava. The crystal is attached to the walls by slender, needle-like filaments of glass, as shown in the accompanying photographs (Figs. 4 and 5). There may be several explanations of the formation of these cavities, but the writer believes they were formed chiefly by the differential movements of the crystal and matrix when the blocks of lava were ejected in a semi-solidified state.

The common sizes of the crystals are 10 mm. to 15 mm. in the

longest diameter, though the largest is 20 mm. or longer. Their surfaces are not vitreous, or smooth owing to the presence of pumiceous matrix and inclusions of olivine crystals with a few magnetite grains. The olivine is in well-defined forms, as already described.

The roughness of the crystal faces and the twin striation upon them made the use of the reflection-goniometer very difficult. Even the cleavage piece used for the measurement of the facial angle (001) : (010) did not give a satisfactory result, as the reflection on (010) was disturbed by the pericline twin striations. The angle measured lies between 85° 48′ and 85° 52′. Other approximate facial angles measured by the contact-goniometer are as follows:

l(110) : M(010)	59° 30′
$\bar{y}$($\bar{2}$01) : P(001)	81° 10′
$\bar{y}$($\bar{2}$01) : M(010)	90° 50′
y(201) : *l*(110)	45° 20′
t(201) : P(001)	42°
n(021) : P(001)	46° 40′

From the above angles and the relation of the crystallographic zones the crystal-faces which were identified have been determined as follows:

P(001), M(010), T(1$\bar{1}$0), *l*(110), *t*(201), *y*(20$\bar{1}$), *e*(021), *n*(0$\bar{2}$1), *m*(11), *o*(11$\bar{1}$), *p*(1$\bar{1}\bar{1}$), and *v*(24$\bar{1}$).

The faces P, M, *y*, T, *l*, *o*, *p*, and *n* are always observed, of which P. M, and *y* are the predominating faces. The face *e* is very rare, and *t*, *f*, *v*, and *m* are only found in the tabular crystal parallel to P(001).

Some distinguishable crystal habits are formed by the predominance of different crystal-faces, as given below:

First type: Prismatic, elongated along the axis *a*, with the faces P, M, and *y* predominating, as seen in Fig. 6.

Second type: Tabular, parallel to M, its elongation being along the axis *c*, as seen in Fig. 7.

Third type: Tabular, parallel to P. This type might be subdivided into two varieties, with gradations between them:

a) The elongation is rather along the axis *a* than along the axis *b*, as seen in Fig. 8.

b) The elongation is along the axis *b*, with specially well-developed *y*, as in Fig. 9, finally becoming thick tabular parallel to *y*.

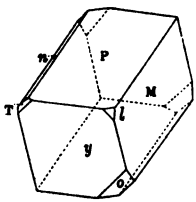

FIG. 6

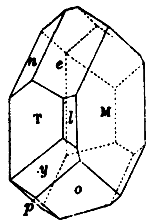

FIG. 7

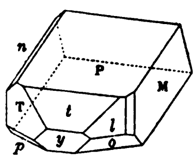

FIG. 8

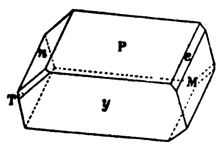

FIG. 9

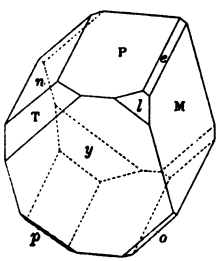

FIG. 10

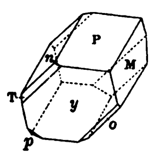

FIG. 11

Fourth type: Cubic, or equant, with comparatively well-developed face *n*. This type might also be subdivided into two varieties, showing gradations into each other or to the first type:

a) With slight elongation along the axis *c*, as seen in Fig. 10.
b) With slight elongation along the axis *a*, as seen in Fig. 11.

The prevailing habits are the first and third types; the second and the *b* type of the fourth are not rare; the *a* type of the fourth is the scarcest.

Twinning according to the Carlsbad, Manebach, albite, and pericline laws has been observed. There are two or more different types in combination. The albite and pericline types occur polysynthetically, while the Carlsbad type occurs in combination with one or both of these. The Manebach is only found in the tabular crystal parallel to P, mostly combined with pericline twinning. The specific gravity measured by the Westphal's balance in Thoulet's solution is 2.759.

Optical characters.—Extinction angles on P(001) and M(010), measured on cleavage pieces, are $-36° 54'$ and $-35° 24'$, respectively. The measurement of the mean index of refraction was made approximately by means of Wright's solution. The solution corresponding to the mean refraction of the mineral was determined on the Abbe total-reflectometer. The result is $n_y = 1.5785$. The measurement of orientation of the optic axis B was made by the Becke method,[1] with single screw micrometer ocular. The values ρ and r of the axis B were measured on three thin slices parallel to P(001). The results are as follows:

(1) On +P(001)

Micrometer parallel $\begin{cases} \rho = -60° \; 44.8' \\ r = \;\; 0.405 \end{cases}$ Micrometer diagonal $\begin{cases} \rho = +28° \; 12.6' \\ r = \;\; 0.337 \end{cases}$

(2) On +P(001)

Micrometer parallel $\begin{cases} \rho = -60° \\ r = \;\; 0.346 \end{cases}$ Micrometer diagonal $\begin{cases} \rho = +25° \; 5' \\ r = \;\; 0.318 \end{cases}$

(3) On −P(00$\bar{1}$)

Micrometer parallel $\begin{cases} \rho = +55° \; 28.5' \\ r = \;\; 0.354 \end{cases}$ Micrometer diagonal $\begin{cases} \rho = -29° \; 11' \\ r = \;\; 0.354 \end{cases}$

[1] Becke, "Bestimmung kalkreicher Plagioklase durch die Interferenzbilder von Zwillingen," *Tschermaks Min. Mitth.*, 1895, Bd. 14, s. 415–42.

From the above figures, the following values for the azimuth of the axis B against the edge P/M on P (ξ) and the true angle-distance (ω) are given:

	ξ	ω
(1)	$-12°$	$19° \ 37'$
(2)	$-12.3°$	$19° \ 14'$
(3)	$-12.7°$	$19° \ 42'$ reduced on $+$P
	$-12.3°$	$19° \ 31'$

For calculation of ω, $n_y = 1.5785$ and $k = 0.141$ were adopted as the mean index of refraction and Mallard's constant, respectively.

From the mean values of ξ and ω, ϕ and λ were given as follows:

	I	II
$\phi=$	$-0.3°$	$-0° \ 17'$
$\lambda=$	$-5.8°$	$-4° \ 23'$

The values under I are results approximately obtained by the construction of the stereographic projection and those under II by calculation.

Plotting the latter values on Becke's diagram, which indicates the relation between the orientation of the optic axis B of plagioclase and its corresponding chemical composition, the composition of the present mineral would be identified as Ab_4An_{96}—Ab_5An_{95}, as shown in Fig. 12.

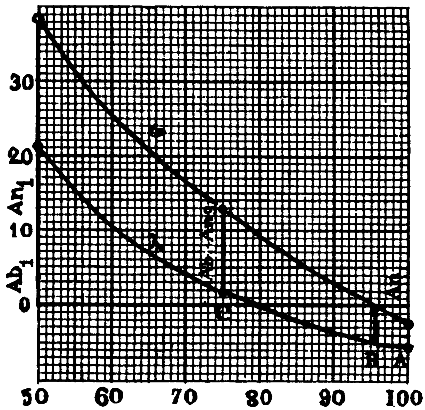

FIG. 12.—In the figure, A is the anorthite from Vesuvius, B is the anorthite from Tarumai, and C is the bytownite from Naeroedal.

The mineral is optically negative with r as the acute bisectrix. The optic angle measured in cedar oil ($n_y = 1.515$) with yellow light, is

$$2H_a = 90° \ 11.5'$$

and its true angle is

$$2V_a = 85° \ 39'$$

Chemical characters.—The mineral is easily attacked by hydrochloric acid, and the powdered sample is readily decomposed with

the separation of gelatinous silica in slightly hot hydrochloric acid of the strength of 22 per cent.

The chemical analysis was made by W. Yasuda in the chemical laboratory of the Imperial Geological Survey of Japan. The sample for the analysis was taken from the clear and fresh part of a crystal, and powdered to grains one millimeter or smaller in diameter. To remove the impure parts, which contained inclusions of olivine, magnetite, and glass, the grains were separated into three portions by Thoulet's solution, having specific gravities of 2.747 and 2.760. The analysis was made of the sample with the specific gravity lying between the two values. The result is as follows:

SiO_2	43.51
Al_2O_3	35.75
FeO	trace
MgO	1.11
CaO	19.48
Na_2O	0.61
K_2O	0.05
	100.53

Subtracting silica and magnesia corresponding to the olivine molecule, and potash as impurity, and calculating the remainder as parts in 100, we have:

	W (percentage)	Mol. prop.
SiO_2	43.30	0.73
Al_2O_3	36.31	0.36
CaO	19.77	0.35
Na_2O	0.62	0.01
	100.00	

From which it is found that the composition of the anorthite may be represented as a mixture of 2Ab and 35An, or $Ab_{5.4}$ $An_{94.5}$, which corresponds closely to the value determined optically as Ab_5 An_{95} —Ab_4 An_{96}.